REPORT

ENGINEERING CONSULTING SERVICES
PHASE I-BACKGROUND STUDIES

PROPOSED DEVELOPMENT OF CRANEY ISLAND DISPOSAL AREA PORT OF HAMPTON ROADS, VIRGINIA

FOR THE

VIRGINIA PORT AUTHORITY

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December 18, 1978

Virginia Port Authority
1600 Maritime Tower
Norfolk, Virginia 23510

Attention: Mr. J. Robert Bray
Executive Director
Commonwealth of Virginia
Virginia Port Authority

Gentlemen:

We submit herewith three copies of our "Report - Phase I Background Studies - Engineering Consulting Services, Proposed Development of Craney Island Disposal Area, Port of Hampton Roads, Virginia, for the Virginia Port Authority."

The objective of the Phase I background study was to collect, review, evaluate and interpret the information which is currently available on the subsoil conditions in the vicinity of the Craney Island Dredge Spoil Disposal Area. Our study was authorized by the Virginia Port Authority by a letter dated September 22, 1978.

Our background investigations have uncovered a substantial amount of information pertaining to the Craney Island area in the files of the Corps of Engineers (Norfolk District) and at the Virginia Department of Highways and Transportation in Richmond. However, we feel that the proposed development of Craney Island will require more accurate information on the extent and depth of the soft subsoils in the immediate area of the proposed construction, on the depth and supporting capacity of the underlying compact sandy soils and on the distribution and characteristics of the dredge spoil materials.

For Phase II of these studies, it is proposed to undertake a detailed foundation investigation program in order to obtain the additional subsoil information which is required and to prepare engineering recommendations for the development of the Craney Island Disposal Area. A detailed proposal for such an investigation is being prepared at this time.

It has been a pleasure to work on this project. If you have any questions or if any portion of the report is unclear, please do not hesitate to contact us.

Very truly yours,

DAMES & MOORE

G. Andrew Reti

G. Andrew Reti
Partner

GAR:gh

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SUMMARY

This report presents the results of our background study conducted to collect, review, evaluate and interpret the information which is currently available on the subsoil conditions in the vicinity of the Craney Island Disposal Area within the city limits of Portsmouth, Virginia.

This background study is the first phase of a two-phase evaluation of the subsoil conditions for potential future development on Craney Island. The second phase will consist of a more detailed exploration and engineering program designed to develop specific engineering recommendations for construction on Craney Island.

Our background investigations have uncovered a substantial amount of information pertaining to the Craney Island area in the files of the Corps of Engineers (Norfolk District) and at the Virginia Department of Highways and Transportation in Richmond. The Corps has conducted extensive subsoil investigations, laboratory tests and engineering analyses prior to the construction of Craney Island. More recently the Corps also conducted additional investigations in connection with a proposal to raise the Craney Island containment dikes to elevation +30 (MLW)*. The Virginia Department of Highways and Transportation also has conducted extensive subsoil investigations for a new bridge crossing for Highway I-664 at Hampton Roads. Other sources of subsoil information which we have also consulted during this study are described later in this report.

The information we have collected proved to be very useful in defining the general subsoil conditions in the Craney Island area and in identifying

* All elevations mentioned in this report refer to Mean Low Water (MLW).

the potential foundation problems to be anticipated in the development of commercial, industrial and harbor facilities on Craney Island. However, more detailed investigations will be needed to define:

1. the extent, depth and physical properties of the soft marine sediments underlying the dredge materials,
2. the depth and supporting capacity of the firmer sandy soils underlying the marine sediments which would have to be used to support heavier structural loads, and
3. the extent, depth and physical properties of the near-surface dredge materials which may be used to support lighter structural loads.

Under separate cover we plan to submit to the Port Authority a detailed proposal to conduct the engineering investigations which would be required.

AVAILABLE INFORMATION

Subsoil Investigations

Prior to its development for dredge materials disposal, the site consisted of a shallow offshore area to the north of Craney Island. The waters varied in depth from the shoreline to a maximum of 12 feet about two miles offshore, where the proposed east-west trending north dike of the disposal area was to be constructed. A sand bottom extended out from the shore approximately 3000 feet, after which the bottom consisted of a marine clay.

During the initial planning for the dredge materials disposal area in 1944, the Corps drilled a series of 17 Gow type borings along the center-line of the proposed containment dikes. No samples were obtained from these borings which were drilled to a maximum depth of 125 feet or to hard compact sand. Although these borings are mentioned in the Corps' "General Design Memorandum" of March 24, 1953 no boring logs could be found.

The initial explorations conducted by the Corps in 1948 for the design of the dredge disposal area consisted of five borings numbered 22 through

26, spaced approximately 5000 feet apart along the dike centerline. The locations of these borings are shown in Figure 1. Frequent, undisturbed samples (Shelby tubes) were taken in the borings and each boring was drilled to hard compact sand.

In 1949, the Corps drilled a second series of six borings numbered 81 through 86 (see Figure 1), located along the dike centerline and spaced approximately midway between the previous borings. These borings were carried to hard compact sand and were selectively sampled. Unfortunately the logs for the 1948 and 1949 Corps borings do not show the driving resistance of the soils. This information would have helped establish the relative consistencies of the various soil layers. Copies of the 1948 and 1949 Corps of Engineers boring logs are reproduced in Attachment 1. Extensive laboratory tests were conducted on soil samples obtained from the 1948 to 1949 borings to help identify and classify the soils and to investigate the strength, compressibility and permeability of the soil samples.

In addition to the deeper foundation explorations, conducted along the dike alignment, 40 additional shallow borings were drilled by the Corps near the natural shoreline of Craney Island, to determine the quantity and types of materials available for dike construction. The sand discovered in these shallow borings was found to be reasonably uniform and suitable as borrow material for the dike. However, these borings are too shallow to provide useful information regarding the deeper subsoil conditions at Craney Island, although they do help delineate the boundaries of the sandy soils along the western portions of the Island.

In October 1955, the Raymond Concrete Pile Co. drilled eight borings, ranging between 51 and 100 feet in depth, between the east dike of Craney Island and the Norfolk Harbor Channel (see Figure 1). All these borings encountered extremely soft silty and clayey marine sediments to their full depths. Only one boring encountered sand at a depth of approximately 45 feet. These boring logs are reproduced in Attachment 2.

From 1968 to 1970, Dames & Moore drilled nine borings along the south boundary of the Craney Island dredged materials disposal area in connection with the foundation investigation for a proposed 230-kv transmission line for the Virginia Electric Power Company. Seven additional borings were located on the Norfolk side of the channel (see Figure 1). The borings near Craney Island show a surface blanket of sand and silty sand underlain by varying thicknesses of soft to moderately soft clay and silty clay. These boring logs are reproduced in Attachment 3.

In 1971, the Corps conducted a new investigation to determine if the storage capacity of Craney Island could be increased by raising the containment dikes to elevation +30. Three undisturbed sample borings (numbered CI-1, CI-2, and CI-3) were drilled as near as possible to the 1948 undisturbed sample borings (see Figure 1) to compare soil samples obtained at similar depths and to detect any change in soil properties due to the weight of the dike during the elapsed 23 years. Eleven additional shallower borings (numbered CI-4, to CI-20) were also drilled within Craney Island (see Figure 1). These boring logs are reproduced in Attachment 4.

For the design of the I-664 bridge crossing of Hampton Roads, Sverdrup and Parcel drilled 13 offshore borings in April of 1972. Two of these borings (Nos B-8 and B-9) are located approximately 3/4 mile west of the west dike of Craney Island (see Figure 1). These boring logs are reproduced in Attachment 5.

In 1976, 16 borings were drilled by URS/Madigan-Praeger, Inc. to investigate the subsoil conditions for Container Berth No. 3 in Norfolk. Although these borings are located on the east side of the Norfolk Channel, across from Craney Island (see Figure 1), they are useful in defining the depth and extent of the soft marine clays and silts underlying the general area. These boring logs are reproduced in Attachment 6.

Currently, the Virginia Department of Highways is having additional offshore borings drilled along the alignment of the proposed I-664 crossing of Hampton Roads (see Figure 1). The logs of the borings located in the general vicinity of Craney Island are reproduced in Attachment 7.

Laboratory Test Results

Extensive laboratory tests were conducted on the samples obtained from the borings drilled during the 1948 and 1949 Corps investigations.

Currently laboratory tests are in progress on soil samples extracted from the borings drilled for the I-664 crossing of Hampton Roads. These tests are being conducted by the Virginia Department of Highways and include identification tests, strength tests and consolidation tests. They offered to make their results available to us when the tests are completed.

Based on the 1948 and 1949 investigations, the Corps divided the subsoils in the Craney Island area into four horizontal soil strata identified as A,B,C and D as shown in the table below:

Zone	Depth Below MLW	Soil Type
A	-10 to -30 feet	very soft gray marine clay
B	-30 to -60 feet	soft gray marine clay
C	-60 to -90 feet	marine clay mixed with some silt
D	-90 to -110 feet	clay and silt with some sand
	below -110 feet	compact sand

These strata limits were not considered definite and were selected arbitrarily, primarily in an effort to recognize a variation in the clay foundation from the recently deposited soft organic materials near the surface, to the firmer layers at greater depths. The compact sand was established as the rigid boundary limit necessary in the theoretical analyses of stability and settlement.

Laboratory tests on the soil samples included tests to determine the following soil properties:

Specific gravity
Unit dry weight
Water content
Void ratio
Atterberg limits
Direct and Triaxial shear strength
Permeability
Consolidation

Figure 2, reproduced from the Corps of Engineers, summarizes the test results on the four soil zones described above. Copies of more detailed test results are available in our files.

It should be noted that no laboratory tests were conducted on the deeper sandy soils below the soft marine sediments. The purpose of the 1948 and 1949 Corps studies was to investigate the stability and the anticipated settlement of the dikes and the dredged materials disposal area. Therefore, there was no need to investigate the physical properties of the deeper sandy soils at that time. Also, the '48 and '49 investigations were conducted prior to any deposition of dredged materials. Therefore no laboratory tests could be conducted on the dredged deposits. The engineering properties of the sand fill used for dike construction were assumed, based on values obtained from published text books for clean sandy soils.

Engineering Analyses

The stability of the proposed dredged materials containment dikes was investigated by the Corps, by means of critical slip circle analyses. These analyses produced stability ratios ranging from 1.89 to 5.3, indicating that the proposed embankment section and foundation were adequately safe against a sliding type failure immediately after construction.

Analyses based on the theory of elasticity, showed that the calculated stresses in the top portion of the Zone A soils would exceed the shear strength of the marine clay over a considerable portion of the foundation. Displacement of the soft clay near the top of Zone A was anticipated. This would produce an intermixing of embankment and foundation materials. The designers assumed that no major displacements would occur since the overstressed zone would be completely surrounded by materials not stressed to full capacity. Therefore loads would be transferred from the overstressed to the understressed materials and a major failure was not expected to occur. Subsequent construction experience however showed that large mud waves did occur during the construction of the sand dikes over the soft clays. Special construction techniques had to be used to prevent producing major mud waves during the construction of the dikes.

The sliding wedge analysis produced stability ratios on the order of 1.05 to 1.78 depending on the shear strength assumed in Zone A. The potential instability of dike sections, indicated by these analyses, was confirmed by the mud waves which occurred during construction. The anticipated displacement of the soft marine sediments predicted by these analyses did occur during construction. Adjustments were made both in construction techniques and in the predicted volume of materials needed for dike construction to allow for these displacements.

Based on the laboratory consolidation tests, settlement analyses were performed to predict the vertical displacement of the dikes and the rate at which settlement was expected to take place. The predicted maximum ultimate settlement, at the centerline of the dikes, using average values of soil properties, was approximately 7½ feet. This settlement was expected to occur very slowly, with one half of the ultimate settlement taking place during the first 15 years after the start of fill operations. Copies of the stability analyses and of the settlement analyses obtained from the Corps are available in our files.

During 1971 three borings numbered CI-1, CI-2, CI-3, were drilled as close as possible to borings numbered 22, 26, and 23 respectively, which were drilled during the 1948 investigation. The purpose was to try to obtain a direct correlation between the data obtained in 1948 and the soil properties in 1971. Undisturbed samples were obtained at elevations matching those in the previous borings. Laboratory tests were conducted to determine if the elapsed 23 years has resulted in an increase in the soil strength or a decrease in its compressibility.

A detailed study was performed on the feasibility of raising the dikes to elevation +30. The analyses concluded that raising these dikes is feasible from a stability point of view. However, modifications to the existing dikes and strict construction controls of the new dikes would be required. The upward extension of the +30 elevation dikes must be located a minimum distance of 700 feet inland from the centerline of the existing perimeter road dikes.

EVALUATION AND INTERPRETATION

As described in previous sections of this report, we have identified
ine separate subsoil investigations in the general area of Craney Island.
uring our review of these subsoil investigations, we constructed seven
ery rough cross-sections along various portions of Craney Island and
n its immediate vicinity, to help visualize the subsoil conditions iden-
:ified during the various investigations. These rough cross-sections
nave not been included in this report but are available in our files.
The following is a brief discussion of the findings and our interpretation
of the results of each investigation.

Corps of Engineers Investigations (1948-49)

During the Corps of Engineers' investigations of 1948 and 1949 a
total of 11 borings were drilled around the perimeter of the proposed
dike for the dredge materials disposal area. These borings show that
along the west dike alignment, the nearshore subsoils consist of a relative-
ly thin surface blanket of sand, underlain by gradually increasing depths
of soft marine clay. Below these soft marine sediments there are compact
sands encountered at a depth of about 25 feet near shore, but ranging
in depth between 95 and 120 feet further offshore, depending on the location.
The borings were not drilled very deeply into the underlying sand and
therefore there is no assurance that the sands may not be underlain by
additional soft materials.

The borings along the north dike alignment indicate very soft organic
clayey and silty marine deposits along the full depth of the borings.
The deeper sand layers were encountered at depths ranging from 80 to about
105 feet. Again the borings were not drilled very deeply into the under-
lying sand.

Along the east dike alignment, the borings show subsoil conditions
similar to those along the west dike. Inshore the surface layer of sand
is very shallow, ranging in depth from about seven feet to about 20 to
50 feet, depending on the location. This surface layer is underlain by
soft marine silts and clays to a depth of about 80 feet. Below these
soft soils there are compact sands extending to the maximum depth of the

borings. Further north, the subsoils consist of soft marine clays of high organic content, underlain by compact sands varying in depth from 93 to about 104 feet. One boring (number 83) was drilled to a depth of 115 feet without encountering any compact sand at all. This indicates the extreme variability of the subsoils in the area and the need for more extensive field explorations for the development of the Craney Island disposal area.

Raymond Concrete Pile Co. Investigations (1955)

The 1955 borings drilled by the Raymond Concrete Pile Co. show that the subsoils offshore from the southeast corner of Craney Island consist of a mixture of silt and sand to a depth ranging between 36 and 47 feet. Further north the subsoils grade into a very soft gray clayey marine silt to a depth of 100 feet, the maximum depth of the borings. The penetration resistance of the organic marine silt was very low. The sampler penetrated the soils usually under the weight of the drill pipes and the hammer, without necessitating any blows. Some of the deeper materials had a driving resistance of only one or two blows per foot. The supporting capacity of the soils encountered in these borings is very limited.

Dames & Moore Investigations (1968-70)

The 1970 Dames & Moore investigation for the Virginia Electric Power Company was located along the south edge of the dredged materials placement area. The borings generally revealed a blanket of silty and sandy soil near the ground surface, underlain by gray silty clay at depths ranging from 12 to about 30 feet below the ground surface. The clayey and silty soils were moderately firm, requiring between five and ten blows per foot of penetration on the Dames & Moore sampler. The sandier soils were more prevalent along the west, with increasing depths of clayey soils along the east. The Dames & Moore borings drilled on the other side of the Norfolk channel also showed the presence of thick layers of clayey soils of about the same firmness. The transmission line towers are supported on long friction piles developing their support in the moderately firm clayey soils.

rps of Engineers Investigations (1971)

The 1971 borings by the Corps were drilled as close as possible to ome of the previous borings drilled in 1948, in order to compare the oil properties and to determine if any consolidation had taken place uring the elapsed 23 years.

The Corps concluded that there has been no significant increase in oil strength since the construction of the project. The average values f cohesion and friction between the 1948 and the 1971 test results are ery similar. A comparison of the boring logs indicates that approximately ive feet of settlement has occurred. Settlement ranged from a low of hree feet at the northeast corner to a high of 6.6 feet at the northwest corner.

Periodic profile surveys are conducted by the Corps to measure the settlement of the dikes. These surveys show substantially less settlement at the southern portion of the dikes, indicating the less compressible nature of the subsoils in these areas.

Sverdrup and Parcel Investigations (1972)

In 1972 Sverdrup and Parcel drilled seven borings approximately 3000 to 5000 feet west of the west dike of Craney Island. These borings generally confirmed the subsoil conditions found by the Corps in 1948 and 1949 during the initial Craney Island investigation along the west dike.

URS/Madigan-Praeger Investigations (1976)

The borings drilled for Container Terminal No. 3, located on the east side of the Norfolk channel, generally confirmed the existence of the soft organic marine clays below a blanket of silty sand near the ground surface. Firmer soils consisting generally of stiffer clays were located between 35 and 70 feet below ground surface. Occasionally firmer sands were also found at these depths.

Virginia Department of Highways Investigations (1978)

Borings currently being drilled by the Virginia Department of Highways generally confirm the existence of deep soft marine clays and silt in the offshore areas and firmer silty and sandy soils located near surface, ser to shore. If the westward extension of Craney Island is authorized the future, the proposed Hampton Roads bridge trestle will limit the ward boundary of the disposal area. The Virginia Port Authority is sently working with the Virginia Department of Highways & Transport- on to determine the location of the westward levee in order to avoid erfering with the trestle structure of I-664.

ratory Tests and Engineering Analyses

Extensive laboratory tests and engineering analyses were conducted connection with the initial investigation of the materials disposal and in 1971 for the design of the higher dikes. These tests and lyses are generally sufficient to establish the principal soil properties the soft organic marine silts and clays located below Craney Island.

The stability analyses carried out by the Corps, generally predicted satisfactory performance of the dikes and anticipated the displacement some of the very soft silty clays under the weight of the dike. The tlement predictions for the dike were generally accurate. Ultimate tlements on the order of 7½ feet were predicted and between three to e feet of settlement has already taken place along various sections the dike. The rate of settlement appears to be somewhat faster than t predicted during the initial investigations. However, the variable ure of the subsoils makes settlement prediction very difficult in this a.

mary of Boring Log Data

Next to each boring location, shown in Figure 1, we have indicated total depth of the boring and the reported depth to the firmer sand atum which may be suitable for foundation support.

In some borings there were intermediate sand layers, underlain by soft rine deposits. In these borings, the depth to sand, shown in Figure 1, es not represent the depths of these intermediate sand layers. Some rings were stopped after only a few feet of penetration into sand. There- re, there is no assurance that these sands are suitable for foundation pport without drilling deeper into the subsoils.

The information regarding the materials encountered in the borings and the depth to sand, shown in Figure 1, is based on data and interpretation by others and must be used with caution. It is subject to revision based on data developed during subsequent field explorations.

Other Information

During our discussions with the Corps of Engineers, we learned of a Japanese dredge materials stabilization method which may be applicable on Craney Island. The method, called the Takenaka Deep Chemical Mixing (DCM) method, consists of the injection and mechanical dispersion of a cement slurry into the soft dredge materials to solidify them. Although the DCM method appears attractive, our initial impression is that it is also very expensive. We have contacted the manufacturer for further information.

Additional background information on the geologic history of the Hampton Roads and James River area is apparently available from the Division of Mines and Resources of the State of Virginia and from the Department of Geology at William & Mary. We plan to contact these sources if our future studies warrant the need for such information.

ADDITIONAL DATA REQUIREMENTS

The proposed development of Craney Island will require more accurate information on the extent and depth of the soft marine sediments in the immediate area of the proposed construction. Subsoil information is currently available only at widely spaced locations in the vicinity of the borings that were drilled during the past thirty years. Once the general area for development has been delineated, a more detailed subsoil exploration program needs to be conducted to investigate the extent and depths of the soft soils.

The depth and supporting capacity of the underlying compact sandy soils must also be investigated in greater detail. Most of the earlier borings which reached these sandy soils stopped after a few feet of penetration. It will be necessary to investigate to a greater depth the extent of these soils, in order to ascertain that they are not underlain by softer layers. The physical properties of the sandy soils and of the soft clay need to be evaluated in greater detail in order to develop information for foundation design.

The extent, depth and physical characteristics of the dredge materials must also be investigated in order to evaluate the supporting capacity of these soils for pavements and lighter structures. The possibility of shifting some of the sandy dredged materials and regrading certain areas, utilizing some of the more granular materials in the dredge materials areas, should also be investigated.

Respectfully submitted,

DAMES & MOORE

G. Andrew Reti

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Partner